Biathlon Shooting Training with SCATT-Simulator
Accuracy Shooting Training of Young Biathletes

Elena Plotskaya and Anna Zakharova
Institute of Physical Education, Sport and Youth Policy, Ural Federal University, Mira Street, Ekaterinburg, Russia

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Abstract: Teaching marksmanship to beginners in biathlon is extremely difficult. The usage of SCATT shooting simulator system, its software and shooting parameters interpretation are under consideration. Methods. A group of 12 well-trained young biathletes (6 males and 6 females), 14-19 years old, with 3-5 years of training experience in skiing and biathlon were recruited as participants. Every athlete had 0.5 hours of SCATT-shooting 3 times per week. Each athlete's shooting parameters were measured on the 1st, 10th, 18th and 21st days of our experiment. Results. Novices in shooting decreased the average aiming trajectory length "L" from 434 ± 39 mm to 370 ± 65 mm and improved the graph "Coordination" line and its location within the target zone in biathlon standing shooting. The average shooting "Result" was 4.5±1.08 in novices (enough for biathlon standing shooting). All young biathletes with 3-5 years of shooting experience corrected the shooting aiming errors. The dynamics of "L" is individual and too dependent on the athlete's fatigue degree.

1 INTRODUCTION

Biathlon is a worldwide-popular spectator sport combining cross-country skiing and small-caliber rifle shooting. Biathlon shooting is highly demanding because it has a number of specific features:

- competition rules factors (a shooting round of 5 shots, 2 or 4 shooting rounds per race depending on the event and, moreover, on a background of high physical fatigue due to cross-country skiing);
- physiological factors (high heart rate and lactate level caused by high intensity of skiing race);
- psychological factors (physiological arousal, mental judgment, fast shooting, unexpectedness, shooting in contact with other competitors and a large number of spectators);
- challenging environmental factors (wind, low temperature, and lighting).

The cost of poor shooting is very high in elite biathlon: each miss means additional 150 meters of penalty loop skiing or 1 minute of penalty time according to the rules.

Teaching marksmanship to beginners in biathlon is extremely difficult as the shooting mistakes are hard to find and hard to explain in the shooting range. Shooting training requires not only coaching skills and experience, but also technological support by means of feedback, that is, shooting simulation systems.

Shooting simulation systems (Soetenjio, 2011, Zvereva, 2015, Merlo, 2010, Raphael, 2009, etc) are popular and have been widely used in the armed forces, shooting sports, hunting societies and biathlon for more than 20 years. Simulators are bulletless, silent, safe, simple and inexpensive shooting skills training devices. The most commonly used simulators in biathlon are digital electronic-laser system such as SCATT shooting training system (Russian Federation) (http://www.scatt.com), Noptel Sport II 50 shooting training (Finland) (http://www.noptel.fi), HoRa 2000 L − Laser Biathlon System (Germany) (http://www.hora2000.de) and AO "Eko-Aims" (Finland) (http://www.eko-aims.com). The shooting simulation system action is based on infrared radiation and the principle of camera operation. The software shows the rifle movement during the aiming, trigger handling\processing and the score.

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The Finnish armed forces used AO "Eko-Aims" (Finland) in reservists' shooting training. The Eko-Aims E-BSS shooting system is designed for visually impaired biathletes based on their needs. The system is officially approved by the International Paralympics Committee and is used in World Cup competitions, and in Paralympics. Hearing is used to compensate for sight deficiency in this type of shooting. (http://www.eko-aims.com).

HoRa 2000 L - Laser Biathlon System is mountable on any Anschütz-Biathlon-Rifle and the shooting training is available for the original distance of 50 meters and shorter distances, such as 10 or 5 meters.

Sport Shooting Training with Noptel Sport II 50 (http://www.noptel.fi) is a tool for training with multiple targets. One can use it indoors at 5 - 10 meters distance with the scaled down biathlon target, or outdoors at the real 50 meters shooting distance with 4P38 Prism Group Unit attached to a real-size biathlon target. Noptel Sport II 50 software displays and analyzes each shot providing valuable information about your shooting skills. The application software shows the gun orientation path on the screen in real time and stores the shots to database for closer analysis and review.

With SCATT shooting system (Russian Federation) one can use any type of weapon and simulate shooting at distances up to 1000 meters with aiming at its own electronic target (figure 1). A coach should pay special attention to the aiming trajectory, displayed on the computer screen. The aiming trajectory provides a coach and an athlete with complete information about the aiming accuracy and mistakes made before and while shooting. This information needs to be interpreted in order to find the shooting mistakes and explain what to do to avoid them.

A general **mistake in shooting** is connected with the concentration of attention. The concentration of attention (from the Latin - Con - with, together; Centrum - center) is the intensity of focus on a particular object or part of the activity (Dushkov, 2005, Mozheiko, 2003). The problem of uncontrolled misses occurs due to the unconscious focus reset when an athlete considers the shot having been already completed and pulls the trigger with thoughts about the next shot (thinking about the next shot). In shooting sports it is impossible to get rid of accidental misses completely even in case of elite athletes (Astafiev, 2007, Khuedelien, 2010). But to reduce this error rate staying focused is the task of each athlete.

The graph "Coordination" for shooting novices and experienced biathletes in dynamics during shooting training sessions with SCATT shooter training system is under consideration.

2 DEVICE DESCRIPTION

Figure 1: Shooting with SCATT shooting system (http://www.scatt.com).

The SCATT shooting system simulator consists of the optical sensor, fasteners (to secure the optical sensor on the weapon), the optical target located 5-10 meters from the shooter, the target interface cable, the electronic target control and computer software (Figure 2).

Figure 2: Shooting system simulator SCATT (http://www.scatt.com).

The SCATT shooting simulator operation is based on determining the aiming point coordinates. The aiming points create the shooter's target path. The geometry of the path (aiming trajectory) and its length are determined by the shooter's qualification level.

The SCATT simulator displays online aiming trajectory of each shot and saves it in memory for further shooting analysis. The SCATT shooting simulator provides us with the following data captured or calculated from the series of preferably 10 or more shots:

- Timing indicators: the total time of the shooting, min: sec; the shooting interval as a period of time between shots, min: sec.
- Quantitative indicators: the "Result" parameter of each shot and group shooting and the average score; the "L" parameter which shows the average length of the aiming trajectory during 1 second before the shot, mm.

- Qualitative indicators: time of the aiming point location in 10.0 zone, %; the shot hole group diameter, mm - the distance between the centers of the outermost holes; "aiming point speed graph" before a shot, of the current shot and at the shooting stage (speed, mm/sec); "Coordination" graph.

In our opinion, the SCATT shooting system is the most relevant one for the comparative "shooting technique-result" analysis. Especially effective is the current analysis of the aiming point line displayed on the computer monitor.

The analysis of "Coordination" graphs (Figure 3) allows exploring the deviation of the aiming point from the centre of the target in the final phase of the shot (pulled trigger) during shooting training sessions. The dynamics of this aiming line are individual, like handwriting, with mistakes and specific features, but there are certain patterns (Figure 3).

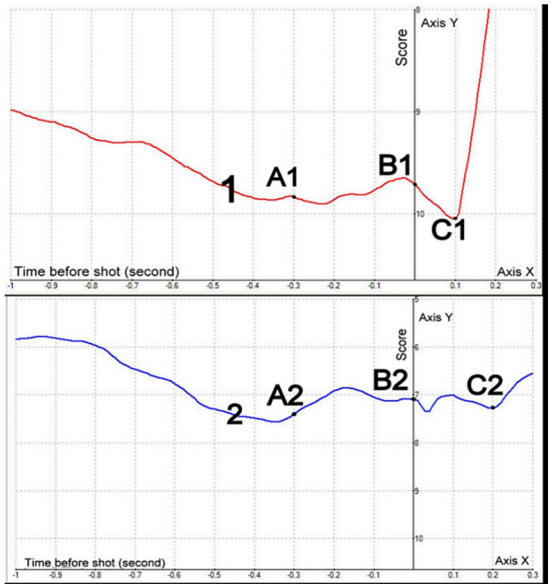

Figure 3: "Coordination" graphs of the elite shooter (line 1) and the elite biathlete (line 2) in a standing position.

The analysis of the "Coordination" graph of a highly-skilled shooter (Figure 3, line 1) revealed that $A_1B_1C_1$-line named 'a shot follow-through' is nearly straight and almost horizontal. Segment B_1C_1 is a short-term retention of concentration during 0,1 sec just after the shot.

The "Coordination" graph (Figure 3, line 2) is an elite biathlete's aiming trajectory. It demonstrates that from the moment of the shot decision (point A_2) to the shot itself (point B_2) there is a loss of 0,4 ± 0,1 points during 0,3 sec.

The segment B_2C_2 'aiming line retention after the shot' is deliberately increased to 0.3 sec., because relatively long concentration retention is necessary, in our opinion, for the biathlon shooting round. Such aiming line fixation immediately after shooting is justified in the specific conditions of biathlon, that is, high heart rate intensity zones, increased tremor, striving to minimize the time an athlete spends at the shooting range, and it also contributes to aligning the rhythm and reliability of the shooting session.

A biathlete is inferior to an elite rifle-shooter in the shooting performance, however, it should be noted that the diameter of the biathlon shooting target for standing shooting is 115 mm, which allows biathletes not to aim at scoring "tens" (the very centre of the target) only (it is enough to hit within the edge of the target to score 4.5 points).

The score lost from the conventional decision-making point (A_1) to the shooting moment (B_1) of an elite shooter is low (0,4 ± 0,25 points), whereas for biathletes it is about 0,75 ± 0,25 points.

3 ORGANIZATION AND METHODS

Subjects. A group of 12 well-trained young biathletes (6 males and 6 females), 14-19 years old, with 3-5 years of training experience in skiing and biathlon were recruited as participants. Subjects № 1,2,3 (Table 2) had no experience in shooting, Subjects № 4-12 (Table 2) had 2-5 years of sport experience in biathlon. The participants' training load was about 30 hours per week including the usual means of biathlon training in preparatory period: roller skiing, nordic walking and cross-country running, shooting on a shooting range, power training and the SCATT simulator shooting.

Research Design. The current research was carried out during 3 weeks in August 2012 with SCATT-simulator shooting. Every athlete had 0.5 hours of SCATT-shooting 3 times per week. Each athlete's standing shooting parameters were measured on the 1st, 10th, 18th and 21st days of our experiment.

At the start of the first shooting training session with SCATT simulator our subjects were informed about the shooting cycle algorithm and the indicators of SCATT shooting which were important to monitor (graph "Coordination").

We assumed that a number of rifle shooting mistakes seen on "Coordination" graph in the shooting simulator SCATT may be easily corrected or avoided. But to enhance biathlon shooting

performance it was necessary to focus the athletes' attention on handling the trigger with coaching verbal instructions (see "Coaching notes" in table 1. And, what is more difficult, to keep their attention concentrated throughout the long shooting round.

The SCATT shooting simulation training was held individually in the evening. Shooting sessions were athlete-friendly without emotional stress.

Simple shooting exercises (Table 1) were selected for training. Exercises are easily done regardless of a biathlete's fatigue.

Measuring Methods. The shooting quantitative indicators were used in our research for monitoring: "Result" - as the average score, points and the length parameter "L", mm. For example, an elite shooter has 45 mm as "L" parameter and 10,04 as "Result" (average score) while an elite biathlete has 120 mm as "L" parameter and 6-7 as "Result".

We used a detailed analysis of the "Coordination" graphs, firstly, for biathletes' correct visual shooting training and, secondly, for the comparative analysis at the beginning and the end of the experiment.

On the lines of the "Coordination" graph (Figure 3) we marked point A at 0.3 sec (X-axis) before the shots, point B (Y-axis) and point C on the graph and 0.1 sec on X-axis crossing and monitored the ABC segment. The ABC segment is called "a shot follow-through" in biathlon,

According to N.V. Astafiev, 2007, aiming accuracy is reduced in case of a sharp rise with the weapon "leaving" the aiming point. The deviation of more than 1.0 point during the 0.3 seconds before the shot (segment AB) is enough for an inaccurate shot. The BC segment indicates the continuation of short-term fixed focus on retaining visual concentration after the shot.

4 RESULTS

Novices' Results in Biathlon Shooting. An example of training progress in average aiming trajectory of novices in shooting at the beginning and end of the experiment is shown on "Coordination" graphs (Figure 4).

In the first training session of our experiment the novice in shooting had a low average result of 3 points on the Y axis and a shot follow-through was weakly expressed (Figure 4, line 1). The shot follow-through (segment $A_1B_1C_1$) was unstable with a break. The aiming coordination of novices in shooting is very low, since it is difficult to keep a rifle within the target. When the weapon leaves the target zone SCATT software cannot determine the aiming points' location. It is the reason for breaks in line 1.

At the end of the experiment line 2 (Figure 4) within A_2B_2 became smoother and closer to the target centre by 2 points (B_1B_2). The novice has noticeably improved the aiming technique of biathlon shooting: the line of aiming is within the target (within 4.5 from the target centre), it is stable without breaks.

Table 1: Shooting simulator SCATT training exercises for biathletes in standing position.

№	Exercises and tasks description	Exercises aims	Coaching notes
1	Hold the aiming line within the target during 3 minutes with the possibility of a short rest.	The development of coordinated actions in the "shooter-weapon" system and coordination endurance.	The attention concentration (mental determination) should be maximal and monitored by the shooter.
2	30 shots following the algorithm: 1. rough targeting; 2. holding breath; 3.precise aiming until a possible shot with the prepressed trigger. 4.closing eyes with the intention to keep the "shooter-weapon" system still; count from 1 to 3 mentally. 5.opening eyes, adjusting aiming and shooting.	Hasty shots prevention. Specific static shooting adaptation. The increase of the static load on the vestibular apparatus. Slow practising of the basic shooting elements for future automatization and speed.	Verbal support and feedback is necessary: "Hold concentration!" Coach words: "See off every shot!"
3	Individual analysis of shooting training.	Explaining the causes of shooting mistakes and determining objectives for further shooting self-improvement.	

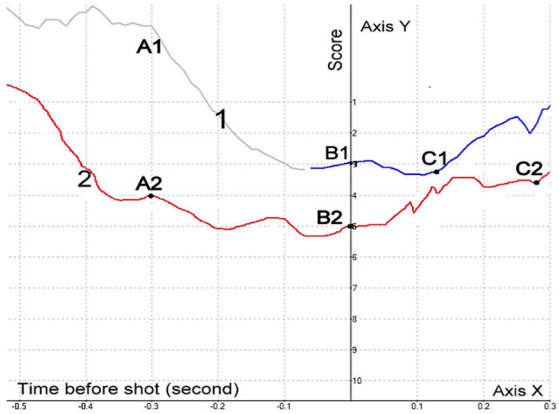

Figure 4: "Coordination" graphs of the novice in shooting (subject №3) at the beginning (line 1) and at the end (line 2) of the experiment.

Novices in shooting (№ 1-3) in the first training session of the experiment had "L" equal to 434 ± 39 mm. On the 21st day of the experimental training after 6 workouts with SCATT novice №1 had a significant improvement in "L" from 474 to 322 mm. The progress in "L" of other novices-subjects is less marked.

During the research novice № 1 progressed from 2.0 to 5.5 in the "Result" parameter. Other novices also achieved the goal demanded by biathlon – a score of 4.5 points - in stressless conditions.

Results of Young qualified Biathletes with 3-5 Years of Biathlon Experience. An example of training progress in aiming trajectory of young qualified biathletes at the beginning and end of the experiment is shown on "Coordination" graphs (Figure 5).

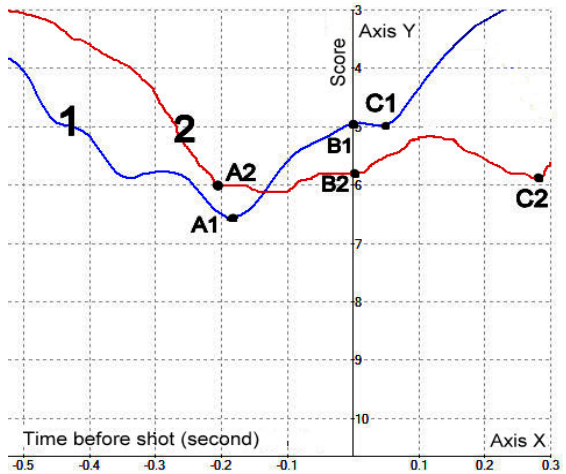

Figure 5: "Coordination" graphs of young biathlete № 6 at the beginning (line 1) and at the end (line 2) of the experiment.

Before the research the young qualified biathlete №6 with 5 years of biathlon experience had a shooting pattern with errors – there was no follow-through of shots after the moment of shot decision (Figure 5, line 1). Such a shooting pattern with errors would prevail under stress in competitions.

In the first training session the following technical error of the shot follow-through was revealed in subject № 6: the aiming curve of the biathlete (Figure 5, line 1) showed a certain tendency in the 0.5-0.2 seconds before the shots - it was directed towards the centre of the target, but at the last moment (0.2 seconds before the shot) the weapon drifted away from the target thus reducing the effectiveness of aiming. The result was 5 (C_1), and it was enough for biathlon standing shooting (4.5 scores), but it was obtained in stressless conditions of training. A shot follow-through was not accentuated (B_1C_1) either, that is why our prognoses about the success of biathlon shooting in competition was not good and the subject needed to correct the aiming technique.

At the end of the experiment the error in a shot follow-through (Figure 5, line 2) was corrected: the average curve of aiming after 0.2 seconds before the shot became directed towards the target, weapons remained at about 6, thus guaranteeing a successful shot. The follow-through of shots became intentionally extended up to 0.3 seconds after the shot, the B_2C_2 segment stayed horizontal. If you compare curves 1 and 2 (Figure 5) you can see that the shooting effectiveness increased (up to 0.8 in the average score). This improvement also increases the chances of accurate shooting under stressful conditions during competitions.

In the first training session of the experiment qualified biathletes (№ 4-11, Table 2) had 361 ± 60 mm of "L" (average length of the aiming trajectory). The degree of shooting performance improvement is individual but only № 9 had good progress of "L" at the end of the experiment

By the 18th day of our experiment the subjects showed their best shooting performance growth in comparison with "L" at the beginning of the experiment (№ 4, 5, 8, 10, 12 showed a decrease in "L" of about 86, 19, 36, 30, 47 mm respectively). The last training micro cycle of three days was designed to be physically hard with increased power load of cyclical nature.

Table 2: Dynamics of quantitative indicators of SCATT simulator in young biathletes (n = 12).

Participant's №	the 1st day		the 10th day		the 18th day		the 21st day	
	L, mm.	Result, score	L, mm	Result, score	L, mm	Result, score	L, mm	Result, score
1	474	2,0	391	4,2	425	1,9	322	5,5
2	448	1,9	569	2,4	484	3,9	462	3,0
3	380	3,0	329	2,4	330	3,2	326	5,0
4	391	4,5	319	4,0	305	4,6	410	4,9
5	486	2,5	416	3,0	467	3,6	497	3,2
6	354	5,0	282	5,3	353	5,8	359	4,3
7	288	4,7	364	4,4	406	5,0	497	3,9
8	328	2,9	345	4,9	292	5,3	305	4,2
9	368	3,6	276	4,7	310	5,2	295	5,4
10	309	5,1	301	4,1	279	4,8	290	4,8
11	404	3,9	385	2,7	427	3,3	447	3,5
12	323	5,0	312	5,2	276	4,2	286	4,2

In our opinion, the dynamics of "L" is too dependent on the fatigue degree of the athlete's central nervous system. Training during 21 days is very demanding for athletes. The decrease of "L" indicators in some biathletes (subjects № 4, 7) by the last day of the experiment can be explained by the athletes' severe fatigue and exhaustion. But such reductions are temporary.

Qualified biathletes showed the growth of average "Result" (Table 2). That is why obtaining tangible contribution of SCATT shooting training in qualified biathletes requires a longer monitoring than three weeks of training sessions.

5 CONCLUSIONS

The work of SCATT shooting simulator, its main parameters useful and necessary for biathlon shooting teaching and monitoring were presented in the article.

Three parameters of SCATT software: "Result" of each shot and shooting round result, the "L" parameter equal to the average length of the aiming trajectory during 1 second before the shot and "Coordination" graph which shows the aiming trajectory were under consideration in our research with young biathletes.

Biathlon shooting aiming research of athletes with different qualifications revealed that "Coordination" graphs provide shooting coaches with more informative indicators for monitoring and assessment of training process than average path length "L". The "L" parameter can be individually deteriorated or remain unchanged for a long time due to biathletes' physical fatigue during the training process.

The presented method of biathlon shooting skill development proved to be effective and easy to use. The following positive changes were observed in the shooting technique due to SCATT simulator system: stabilization and leveling of the "Coordination" curve within 0.3 seconds before the shot with an important for biathlon shot follow-through and 0.3 seconds after the shot in all subjects. The positive changes in aiming parameters were more expressed in novices. We consider that the biathletes at the initial stage of shooting training should be taught with SCATT shooting simulator.

The achieved changes in the shooting aiming according to "Coordination" graphs of various level athletes will be movement patterns (stereotypes) in case of regular SCATT training. The modification of the old (inefficient) stereotype requires high attention concentration from an experienced athlete. It is also necessary for the development of new correct movement patterns in novices in shooting.

All training shooting files by SCATT software should be kept for future monitoring and analysis of "L" and "Result" parameters and "Coordination" graphs.

The dynamics and timing of adaptive changes induced by specific training loads in biathlon require further research.

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